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INVESTIGATION OF FORCES NECESSARY TO SHIFT BOUNDARY BETWEEN SUPERCONDUCTIVE AND NORMAL PHASES

(A Letter to the Editor)

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We have carried out an experiment to measure the torque acting on a sphere which is in the intermediate state while the sphere turned relative to the external magnetic field.

A lead sphere 8 millimeters in diameter was placed in a Dewar flask containing liquid helium which was in a horizontal homogeneous magnetic field. The sphere was attached to a long glass capillary and suspended by a bronze filament from a knob that turns. With the aid of a calibrated circle and pointer fixed to the upper end of the capillary, it was possible to measure the angle of turn of the sphere relative to the magnetic field; and with respect to the difference in the angles of turn of the knob and pointer it was possible to determine the angle of twist of the filaments, which angle is proportional to the torque.

It was observed that upon turning the knob through a small angle, the sphere was twisted simultaneously through a smaller angle and then stopped. For certain values of the angles, the torque and the angle of turn of the sphere relative to the field were proportional; that is, the sphere behaved like a magnetic pointer; the presence of the torque indicated that the magnetic moment of the sphere made some angle with the external field. After returning the knob to the original position, the sphere also returned to its original position.

During gradual increments of the angle of turn, the torque at first increased directly proportionally to the angle of turn; afterwards at a certain angle, this proportionality was disrupted by an "incipient" creep or slip in the direction of decreasing torque. In the course of time, this slip slowed down and then stopped. Further turning of the knob was invariably accompanied by creep, in consequence of which the torque increased with increase in the angle of turn much more slowly than the case for small angles. Now, upon turning the knob to the original position, the sphere did not return to its original position.

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We recorded the curves showing the dependence of the torque upon the angle of turn of the sphere for various values of temperature, magnetic field, and concentration of the normal phase $X_N = (3H - 2H_K)/H_K$. It appeared impossible to establish any simple mechanism or rule that permitted one to calculate definite values of the torque and angle of turn of the sphere corresponding to initial creep or slip; also, it seemed difficult to express the curve as a function of X_N, H, T.

Measurements of the maximum torque which can act on the sphere due to the magnet field were carried out in the following manner: the filament was twisted a certain number of turns after which the sphere began to turn and then stopped. From the final angle of twist of the filament it was possible to judge the maximum torque. The magnitude of the maximum moment, measured for constant temperature and for various values of X_N (that is, for various field strengths) at the boundaries of the intermediate state($X_N=0$ and $X_N=1$) were reduced to zero by passing through the maximum for $X_N \approx 0.1-0.2$. The reading of this maximum for $T=3.35°K$ ($H=37$ Oe) was equal to 3.4 dyne-centimeters (torque units); for $T=2.90°K$ ($H=78$ Oe) it was equal to 12 dyne-centimeters; and for $T=2.67°K$ ($H=102$ Oe) it was equal to 26 dyne-centimeters.

It is necessary to note that during measurements, the magnitudes of the maximum moment were well reproduced from one experiment to another; in the first series of experiments (for turns through small angles) there was not noticed any regularity or reproducibility.

Of course, the sphere hanging from the twisted filament appears to be a system in a state of disequilibrium. Reorganization of the layers or their shifting of the normal and superconducting phases must lead to a decrease in the angle of twist of the filament; that is, to a decrease in the potential energy. However, the time required to restore equilibrium apparently is very great, since we were not able to note any approach to equilibrium even after a time interval of one hour.

We sincerely thank A. I. Shal'nikov for his interest in our work and his valuable criticism.

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